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著者	Asano Kiyoshi, Ingle James C., Jr., Takayanagi Yokichi
journal or publication title	The science reports of the Tohoku University. Second series, Geology = 東北大学理科報告. 地質学
volume	39
number	3
page range	213-241
year	1968-03-15
URL	http://hdl.handle.net/10097/28800

Sci. Rep. Tohoku Univ., 2nd ser. (Geol.), v. 39, no, 3, p. 213-241, 16 figs., March 15, 1968

Origin and Development of *Globigerina quinqueloba* Natland in the North Pacific

Kiyoshi Asano,* James C. Ingle, Jr.,**
and Yokichi Takayanagi*

ABSTRACT

Globigerina quinqueloba Natland is a characteristic planktonic foraminifer inhabiting temperate-subarctic water masses of the world oceans today. Morphotypes referred to *Globigerina angustiumbilicata* (Bolli) are common to abundant in Miocene deposits at the western and eastern margins of the North Pacific. Both these species are characterized by an average of five chambers in the final whorl and extremely simple morphology. Only subtle differences allow their separation when populations, rather than individuals, are examined. A direct lineage is proposed and illustrated from *Globigerina angustiumbilicata* to *G. quinqueloba* within the Middle Miocene to Recent interval.

Populations of the *Globigerina angustiumbilicata-G. quinqueloba* lineage were studied from Middle Miocene ("*Globorotalia fohsi barisanensis*" Zone) through Pliocene deposits from Honshu Island, California, and the Mohole cores. Recent populations of *Globigerina quinqueloba* were studied from the eastern and western North Pacific as well as from the Sea of Japan. The following characteristics were measured on an average of 20 individuals from each fossil or Recent population; test diameter, diameter of the proloculus, total number of chambers, number of chambers in the final whorl, coiling direction, and character of the last formed chamber and aperture.

Measurements and analysis demonstrate that only three morphologic characters within the lineage exhibit significant variation during the interval studied. These include test diameter, shape of the final chamber and aperture, and spinosity of the test surface. Average test diameter increases from less than 150 microns with in Middle Miocene populations to greater than 200 microns in Pliocene through Recent populations. Specimens with a simple aperture and final chamber are common in Middle Miocene horizons whereas individuals with an aberrant last chamber and lip comprise up to 50 percent of some Recent populations. A qualitative trend is apparent from smooth to hispid tests reflecting a possible change in wall microstructure with time. Oligocene populations have smooth test surfaces, Middle Miocene populations exhibit smooth to finely hispid surfaces, whereas Late Miocene through Recent populations display prominantly hispid surfaces.

The study illustrates a long period gradational morphoseries from *Globigerina angustiumbilicata* to *G. quinqueloba*. Complications in interpretation of morphologic trends arise due to ecophenotypic variation within populations of a given horizon. The subtle nature of variation among simple morphologic characters during the Middle Miocene through Recent interval hinders a clearcut separation of the two species. Moreover, analysis of population characteristics, rather than analysis of individuals, demonstrates the difficulties inherent in the use of species limits defined on the basis of a single type specimen. Nevertheless, arbitrary statistical limits allow individuals assigned to *Globigerina quinqueloba* to be initially recognized within the Miocene "*Globorotalia mayeri*" Zone. Statistically defined populations of *Globigerina quinqueloba* appear initially within the Miocene "*Globorotalia menardii*" Zone.

INTRODUCTION

Globigerina quinqueloba Natland constitutes a characteristic and common member of subarctic to temperate planktonic foraminiferal biofacies in the world oceans today

* Institute of Geology and Paleontology, Tohoku University, Sendai, Japan.
** Visiting Scientist from the Geology Department, University of Southern California, Los Angeles, U.S.A., 1966–1967. Authors names are in alphabetical order, no seniority is implied.

(Bradshaw, 1959; Bé, 1959; Parker, 1962; and others). Several workers have called attention to the morphologic similarity between Recent specimens of *G. quinqueloba* and Neogene specimens referred to *G. concinna* Reuss, *G. ciperoensis* Bolli, and *G. angustiumbilicata* Bolli (Parker, 1962; Saito, 1963; Cifelli, 1965). All these morphotypes represent comparatively simple forms distinguished by an average of five chambers in the final whorl and a lack of any outstanding morphologic character.

As with other ubiquitous, long ranging, temperate water planktonic species this group has received only passing attention in the literature as opposed to the detailed study given more exotic tropical species groups. Indeed, their simple morphology, abundance, and apparent long ranges have created an ambiguous attitude toward their taxonomy. Forms referred to *G. angustiumbilicata* have been reported from Upper Eocene strata (Blow and Banner, 1962), however, this species along with *G. ciperoensis* are commonly restricted to Oligocene and Miocene deposits (Fig. 1). Forms referred to *G. concinna* are usually restricted to the Upper Miocene while *G. quinqueloba* is reserved for forms in Pliocene through Recent deposits (Fig. 2). To date the oldest reported occurrence of *G. quinqueloba* is from the Middle Miocene of New Zealand (Kennett, 1966b; Fig. 2). In the light of the morphologic similarity among these five chambered forms it appears that the various species names have been applied principally on the basis of the presumed age of the strata in which they are found rather than the reverse.

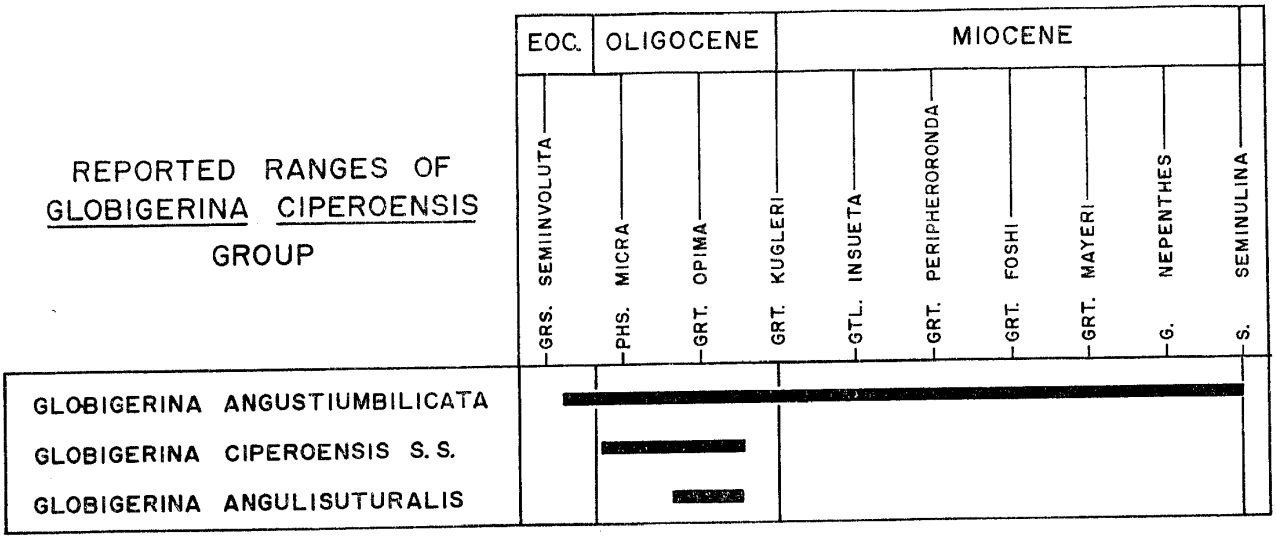


Figure 1. Reported stratigraphic ranges of *Globigerina angustiumbilicata*, *G. angulisuturalis*, and *G. ciperoensis ciperoensis*. The ranges are placed against a scale defined by the upper stratigraphic limits of characteristic planktonic species common to warm temperate and tropical regions.

Globigerina quinqueloba constitutes an average of 5 to 20 percent of temperate planktonic assemblages today. However, Early and Middle Miocene planktonic populations from high latitude areas in the North Atlantic, North Pacific and South Pacific are dominated by forms referable to *G. concinna*, *G. ciperoensis*, or *G. angustiumbilicata* (Marks, 1951; Drooger and Batjes, 1959; Bandy and Kolpack, 1963; Wade, 1964; Jenkins, 1966; Ingle, 1967). It thus appears that *G. quinqueloba* represents one of the current and members of a long established species group inhabiting temperate water masses of the world oceans. This study illustrates some morphologic trends within this species group as traced in Middle Miocene through Recent sediments deposited at the margins of the eastern and western North Pacific.

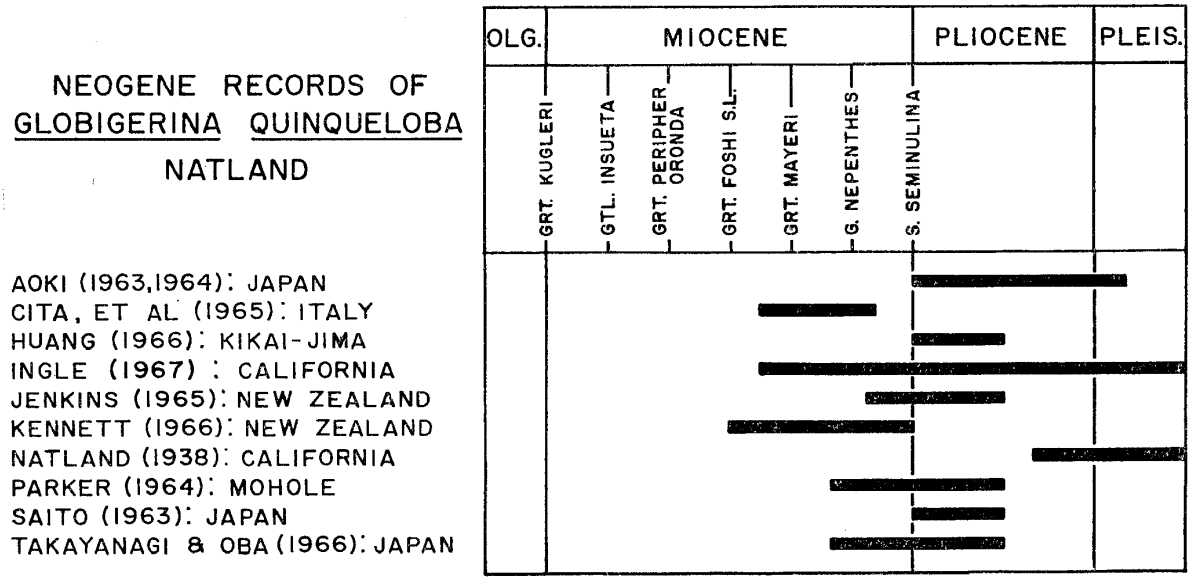


Figure 2. Selected Neogene records of *Globigerina quinqueloba*. In each case the range of *G. quinqueloba* is placed against a scale defined by the upper stratigraphic limits of characteristic planktonic species common to warm temperate and tropical regions.

Problems in Study of Temperate Planktonic Species

Investigation of the *Globigerina angustiumbilicata — G. quinqueloba* lineage clearly illustrates the difficulties inherent in attempting to apply the "type specimen" concept to continuous lineages of planktonic species of simple character. It is readily possible to distinguish some specimens in Recent populations possessing characteristics identical with the type description of *G. quinqueloba*. However, it is also possible to find specimens within the same populations that are identical with the type description of *G. angustiumbilicata*, a form presumably restricted to Eocene through Miocene time. Nevertheless, our study shows that certain morphologic traits within this species group undergo change with time including trends in size, spinosity, and apertural modifications. At any given stratigraphic level a population within this lineage contains individuals exhibiting all morphologic variations developed with the lineage to that point in time. Certain characteristics predominate at any moment. The morphologic characteristics within a population at any given level thus exhibit a Gaussian distribution (Newell, 1956; Imbrie, 1957) with end members and the median form most easily distinguished. It is apparent some workers view such a total population as one taxonomic entity whereas other prefer to split the population into finite groups or in some instances subspecies. In any event, the description of planktonic species is usually not accompanied by a description of variability of the species nor the author's concept of the species limits. The original descriptions of the species under study conform to this pattern (Natland, 1934; Bolli, 1954, 1957; Reuss, 1850) presenting each worker with a basic question as to species definition. The burden of this system in the case of species of simple morphology is severe. The authors do not offer any new solutions to this problem but simply present evidence bearing on a species group of simple construction from an essentially continuous time series.

Location and Method of Study

Planktonic foraminiferal populations were examined from various Middle Miocene through Pleistocene sections in southern California, northern California, and Honshu,

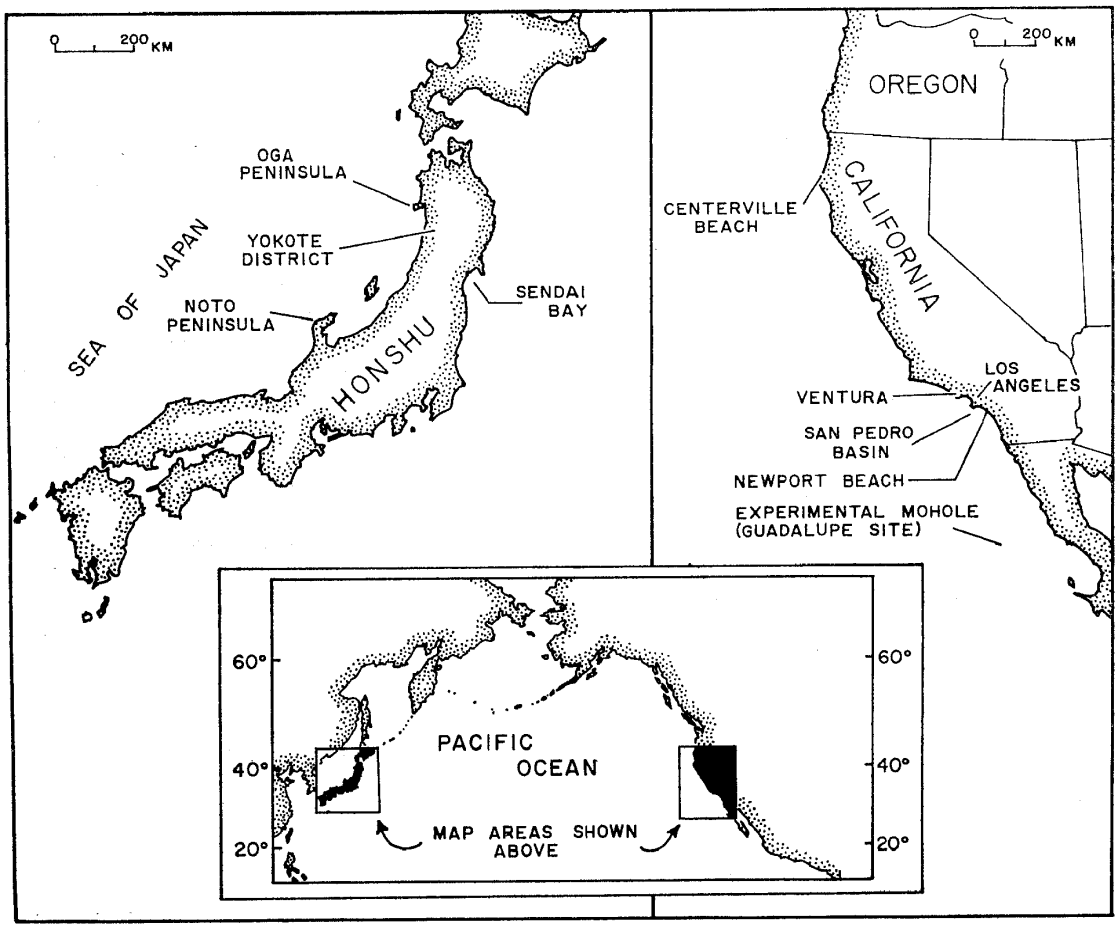


Figure 3. Location map showing North Pacific localities mentioned in this report.

Table 1
APERTURAL CLASSIFICATION

A. Apertural flaps covering umbilical area
   a. Last chamber larger than penultimate chamber (I)
   b. Last chamber smaller than penultimate chamber (II)
B. Aberrant chamber not covering umbilical area
   a. With lip
      (1) Last chamber larger than penultimate chamber (III)
      (2) Last chamber smaller than penultimate chamber (IV)
   b. Without lip
      (1) Last chamber larger than penultimate chamber (V)
      (2) Last chamber smaller than penultimate chamber (VI)
C. Non-aberrant chamber
   a. With lip
      (1) With high-arched opening (VII)
      (2) With low-arched opening (VIII)
   b. Without lip
      (1) With high-arched opening (IX)
      (2) With low-arched opening (X)

Japan (Fig. 3). In addition a suite of samples were studied from the Mohole cores drilled in the eastern North Pacific. Planktonic populations were also examined from Recent sediment samples from off California and Oregon in the eastern Pacific, Sendai Bay in the western Pacific, and from the Sea of Japan.

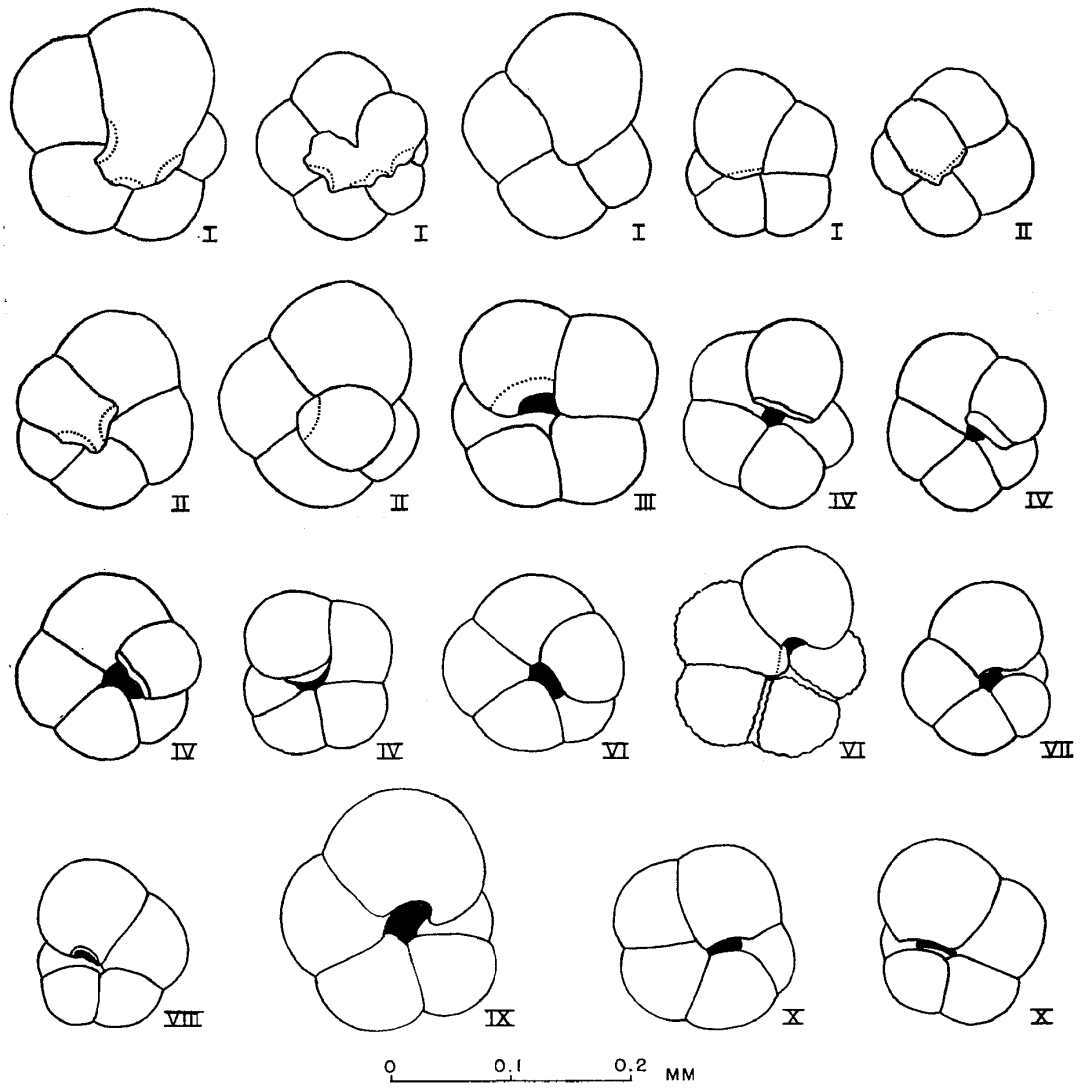


Figure 4. Specimens illustrating the wide morphologic variation in final-chamber configuration found in specimens of *Globigerina quinqueloba*. Roman numerals refer to the classification of final chamber types given on Table 1. Specimens illustrated above were selected from the Wakimoto Formation of Oga Peninsula, Japan. Note that one specimen possessing shape VI also exhibits U-shaped sutures due to the addition of a $CaCO_3$ crust.

An average of 20 specimens from the *G. angustiumbilicata—G. quinqueloba* population from each fossil or Recent assemblage were subjected to the following analysis. Measurements were made of the maximum and minimum diameter, diameter of the proloculus, total number of chambers (including proloculus), number of chambers in the last whorl, coiling direction, and character of the last formed chamber and aperture. Due to the variability of the last formed chamber and aperture a system of classification was devised. A key to the various final chamber forms encountered as well as illustrated examples are given on Table 1 and Fig. 4 respectively. Representative specimens from significant horizons in the various sections studied were illustrated by line drawings.

Thin sections of specimens were not made due to time limitations; thus variation in wall microstructure is not documented and presents a subject for future investigation. It is important to note that a qualitative trend of increasing spinosity and opacity of tests with time was observed. These variations may well signify a significant and accompanying change in the microstructure of the test wall with time.

During this investigation an extensive bilbiography was compiled of papers in which *Globigerina quinqueloba* is cited. These papers are listed separately in a bibliography at the end of the report; the bibliography is exclusive of references cited in the text.

Acknowledgments

The writers are grateful to W. R. Riedel of the Scripps Institution of Oceanography for providing samples from the Mohole cores. Thanks are also extended to A. Bell of the Allan Hancock Foundation, University of Southern California for laboratory assistance, and to Miss M. Abe of the Institute of Geology and Paleontology, Tohoku University for typing assistance. This investigation was largely supported by grant from the Japan Society for the Promotion of Science and U. S. National Science Foundation grant GF 195 as a portion of the cooperative science program between Japan and the United States.

TRENDS IN MORPHOLOGIC VARIATION

Characteristics of Species Studied

It is pertinent to review the specific characteristics attributed to *Globigerina concinna, G. ciperoensis, G. angustiumbilicata, G. angulisuturalis,* and *G. quinqueloba.* Tracings of the original figures of the species in question are presented on Fig. 5 for reference. An immediate problem is that variation within a given species was not presented as a part of the original description of any of these species. Variability of planktonic species is notorious (Parker, 1962; 1965) and it is important that authors state their concept of the morphologic limits of a newly erected species.

Globigerina concinna is the oldest name applied to the forms within the species group studied. Bolli (1954) has reviewed some of the problems inherent in the use of this name and suggested that it be restricted to forms found in Upper Miocene strata. Although the type specimen of this species is lacking, Marks (1951) has provided good illustrations of specimen from populations in the type area. This species is characterized by five large inflated chambers in the last whorl, an open umbilicus, and a large, high arched aperture; it commonly attains a diameter of 400 to 500 microns. The wide open umbilicus, large aperture, and large diameter allow this form to be easily distinguished from *Globigerina angustiumbilicata* or *G. quinqueloba.* Both of the latter species possess a closed umbilicus and relatively small low arched aperture. However, *G. concinna* and *G. ciperoensis s.s.* appear to be essentially synonymous; *G. ciperoensis* was recognized as closely allied to *G. concinna* in the original description (Bolli, 1954). Wade (1964) has already presented the case for considering *G. concinna* as the parent of *G. bulloides.* Morphology of the two species differs principally by the reduction in number of chambers in the final whorl from five in *G. concinna* to four in *G. bulloides.* It is significant to note that Recent populations of *G. bulloides* contain specimens with a fifth (and sometimes diminutive) chamber in the final whorl (Bé and Hamlin, 1967). These forms are commonly referred to *G. quadrilatera* Galloway and Wissler or in some cases made a subspecies of *G. bulloides* (Ingle, 1967).

Parker (1964) has suggested a tentative relationship between *Globigerina quinqueloba* and *Globorotalia minutissima* Bolli. The writers do not agree with this interpretation and feel that some of the forms included within *G. minutissima* by Parker may actually fall within *Globigerina angustiumbilicata.* Parker's (1962) earlier thought that *Globigerina quinqueloba* was derived from *G. ciperoensis* stock is similar to the interpretation given in this report.

It is likely that Middle and Upper Miocene forms referred to *G. concinna* and *G. ciperoensis s.s.* were originally derived from populations of *G. angustiumbilicata* during the Oligocene in the light of the reported ranges of these species (Fig. 1). However, this

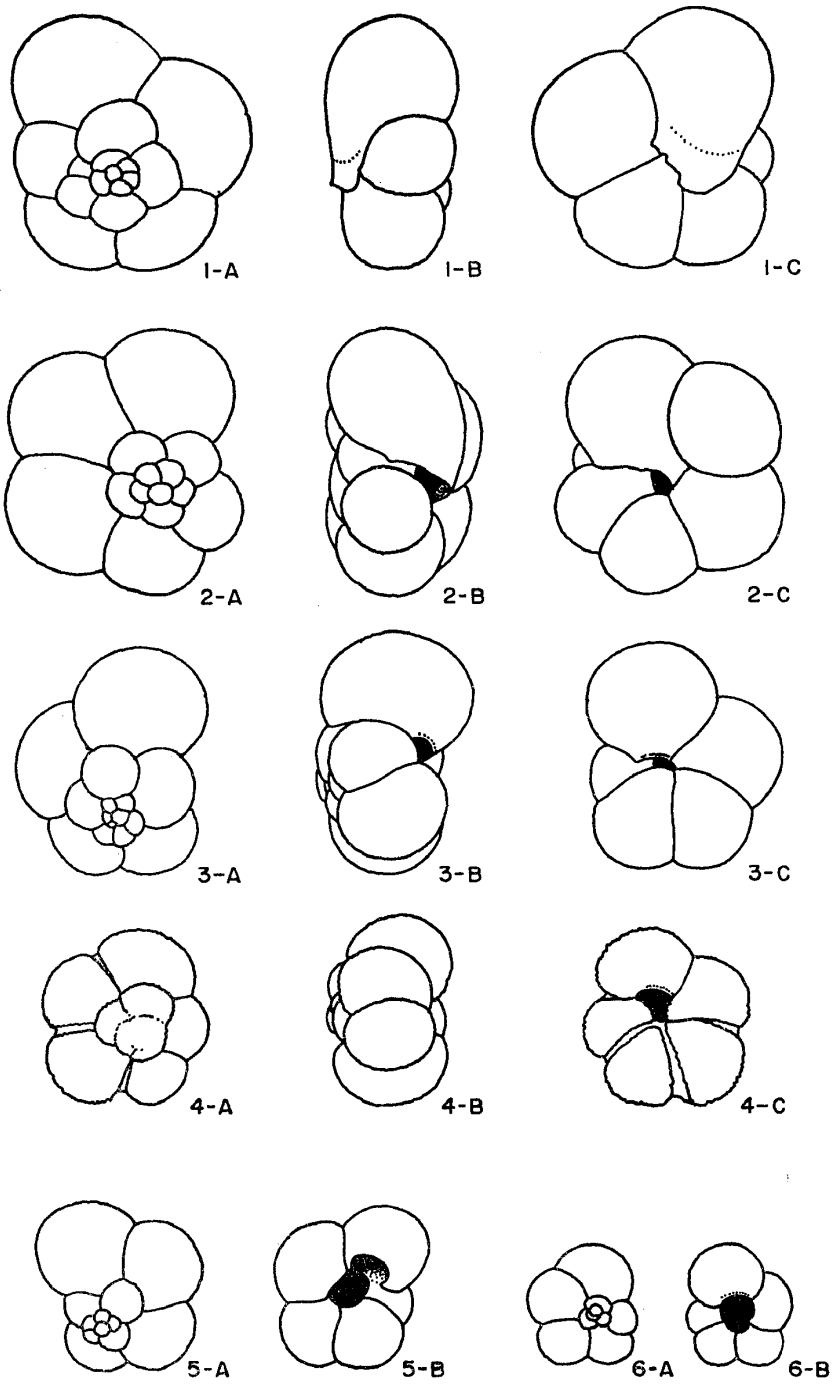


Figure 5. Line drawings of type specimens of principal species of *Globigerina* discussed in this report. Drawings represent tracings of original figures by the respective authors; 1a-c, *Globigerina quinqueloba* Natland, 1938 (×128); 2a-c, *Globigerina tecta* Lipps, 1964 (×152): 3a-c, *Globigerina angustiumbilicata* Bolli, 1957 (×120); 4a-c, *Globigerina angulisuturalis* Bolli, 1957 (×120); 5a-b, *Globigerina concinna* Reuss (×25.6) after Marks (1951); 6a-b, *Globigerina concinna* Reuss, 1850 (ca. ×19.2).

report is restricted to an examination of the apparent direct lineage from *G. angustiumbilicata* to *G. quinqueloba*.

A comparison of the type figures (Fig. 5) and type descriptions of *G. angustiumbilicata* (Bolli, 1957) and *G. quinqueloba* (Natland, 1938) reveal that the principal characteristics separating the two morphotypes are variations of the aperture, final chamber shape,

and in some cases character of the test surface. *G. angulisuturalis* Bolli, a related species, differs mainly by the presence of U-shaped sutures and thick test wall. These characteristics probably reflect the addition of a thick $CaCO_3$ crust to specimens of *G. angustiumbilicata* at depth. Specimens of *G. quinqueloba* with a thick crust of $CaCO_3$ and U-shaped sutures can be found in Recent populations of this species. Lipps (1964) has recently erected a new species, *G. tecta*. He states that this species is distinguished from *G. quinqueloba* by more ovate chambers, five to seven chambers in the last whorl, and a less protruding final chamber over the umbilical area. Specimens exhibiting these characteristics can be separated from Recent populations of *G. quinqueloba*. Thus it is questionable whether a new species should be established for one particular set of variants in a population.

In summary, morphologic characteristics of species erected within the lineage studied suggest there are only two principal forms involved, *G. angustiumbilicata* and *G. quinqueloba*. The following sections document the variation in morphology of these two species with time.

Recent Populations

Before examining variations in fossil forms it is important to illustrate the morphologic variation seen in Recent populations of *G. quinqueloba* from the marginal North Pacific. Parker (1962) has already presented some evidence of the variability within this species. An important character of Recent populations is that they commonly include individuals lacking the protruding lip and chamber over the umbilical area as shown in the type figure of the species (Fig. 5).

Measured characteristics of Recent populations studied and examples of test form are presented on Figs. 6 and 7. Variability of these specimens can be summarized as follows: diameter of proloculus, 11–28 microns; maximum diameter of final whorl, 131–263 microns; total number of chambers (including proloculus), 11–19; number of chambers in the last whorl, 4–6; and coiling random. Counts of final chamber types indicate specimens with apertural flaps covering the unbilicus (as in the type of the species) dominate (Fig. 7). However, specimens with a simple last chamber and small aperture, as seen in *G. angustiumbilicata*, constitute up to 20 percent of some populations (Fig. 7).

Ontogeny of specimens within Recent populations presents an additional insight into their morphologic development. Two dissected specimens from the type area of the species (San Pedro Basin, California) clearly illustrate that the extended lip and aberrant final chamber characterizing this species are only present in adult specimens (Fig. 8). Immature individuals consistently exhibit a simple last chamber and aperture essentially identical with *G. angustiumbilicata* (Fig. 8).

Measurements (Fig. 7) and illustrations (Fig. 6) thus demonstrate that a dominant percent of specimens of *G. quinqueloba* within Recent deposits in the North Pacific possess characteristics identical with the type description of the species. Nevertheless, a significant percentage of specimens possess a set of characteristics placing them within the limits of *G. angustiumbilicata*. Intergrading forms among the morphotypes allow a continuous series of specimens from *G. quinqueloba* through *G. angustiumbilicata* to be assembled from Recent populations.

Recent studies have illustrated that many living planktonic species exhibit ecophenotypic variation in response to differences in water temperature and depth (Parker, 1962; Bé, 1965). The present study did not suggest any specific association between particular morphologic characters within *G. quinqueloba* and variation in oceanographic parameters. Nevertheless, it seems likely that such associations will be revealed by future detailed examination of living populations. Parker (1962) has already detected differences in

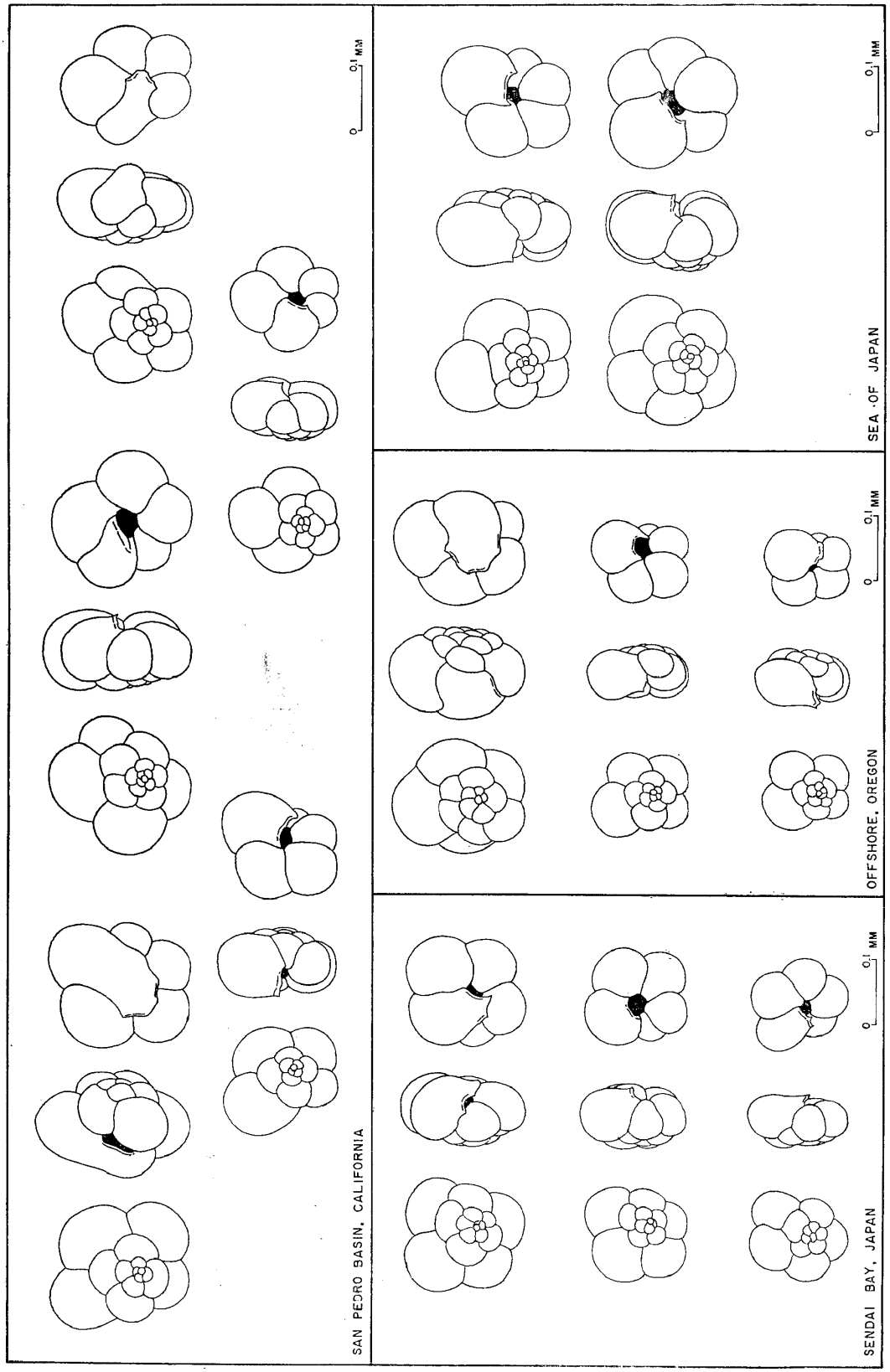
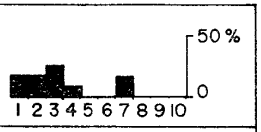
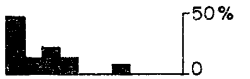
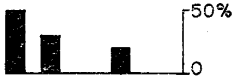


Figure 6. Morphologic variation of Recent specimens of *Globigerina quinqueloba* from various locations in the marginal North Pacific. San Pedro Basin, California represents the type area of the species.

GLOBIGERINA QUINQUELOBA NATLAND

		DIAMETER PROLOCULUS[1]	MAXIMUM DIAMETER FINAL WHORL	MAXIMUM DIAMETER PENULTIMATE WHORL	TOTAL NUMBER CHAMBERS	NUMBER CHAMBERS LAST WHORL	COILING RATIO[2]	NUMBER SPECIMENS MEASURED	PERCENT CHAMBER FINAL TYPES
SEA OF JAPAN	MX.	28	263	150	19	5.7	13/9	22	
	AV.	20	214	106	15	4.9			
	MN.	11	169	81	11	4.0			
SENDAI BAY, JAPAN	MX.	22	224	102	15	5.0	8/11	20	
	AV.	13	180	82	13	4.8			
	MN.	6	131	56	11	4.4			
OFFSHORE, OREGON	MX.	25	250	162	16	5.5	5/5	10	
	AV.	18	199	101	14	4.8			
	MN.	10	150	81	13	4.5			
SAN PEDRO BASIN, CALIFORNIA	MX.	23	250	150	18	6.0	12/9	21	
	AV.	14	205	101	15	5.0			
	MN.	11	144	63	12	4.5			

[1] MEASUREMENTS IN MICRONS
[2] SINISTRAL / DEXTRAL

MX. = MAXIMUM
AV. = AVERAGE
MN. = MINIMUM

Figure 7. Measurements and coiling characteristics of *Globigerina quinqueloba* from various localities in the marginal North Pacific. See Table 1 and Figure 4 for key and illustration of final chamber types noted above.

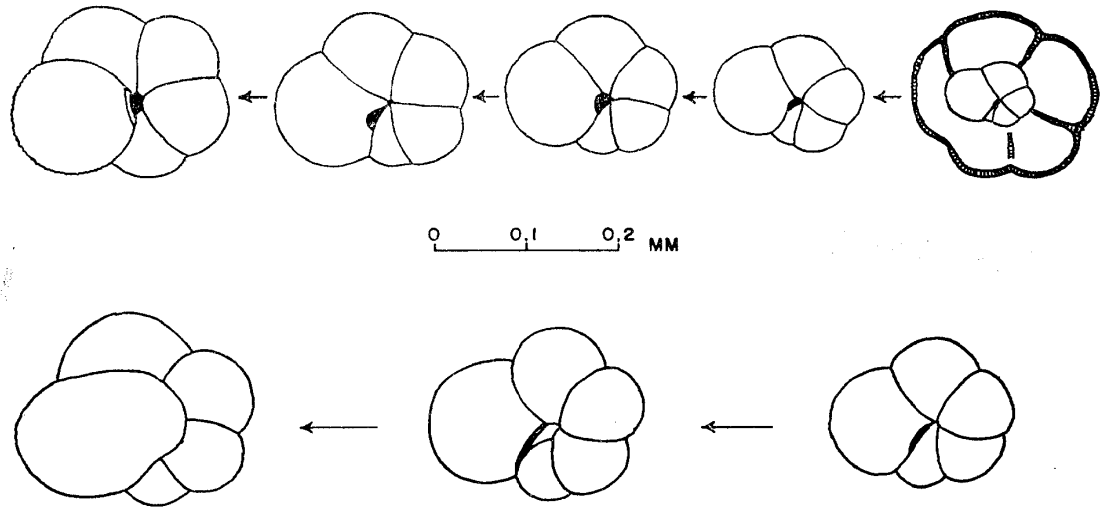


Figure 8. Ontogeny of two specimens of *Globigerina quinqueloba* as revealed by dissection of early chambers. Both specimens were obtained from Recent sediments of San Pedro Basin, California.

aperture modification, spinosity, proloculus diameter, and test diameter among populations of *G. quinqueloba* from different areas in the Pacific. Moreover, Bé and Hamlin (1967) note that specimens of *G. quinqueloba* in the North Atlantic lack an umbilical bulla or infralaminal apertures commonly found in Pacific populations.

Although details of ecophenotypic variation are lacking, studies of living populations of *G. quinqueloba* indicate it can survive in water of 8°C to 25°C but that it prefers temperatures between 11° C to 17°C (Bradshaw, 1959; Bé, 1960; Bé and Hamlin, 1967). It is recognized as one of the characteristic members of the subarctic planktonic biofacies in the Atlantic, Indian, and Pacific Oceans (Bradshaw, 1959; Bé, 1960; Smith, 1963, 1964; Kustanowich, 1963; Parker, 1962; Belyaeva, 1964; Cifelli, 1965; Bé, 1966; Lipps and Warme, 1966).

Neogene Populations

Marginal Eastern North Pacific

Populations within the *Globigerina angustiumbilicata — G. quinqueloba* lineage were examined from two essentially continuous Middle Miocene through Pliocene sequences in the eastern North Pacific. The first sequence is contained within the thick epicontinental Neogene deposits exposed along the margins of the Los Angeles Basin, California (Fig. 1). The second sequence is the thin but unique series of Mohole cores extracted from the abyssal plain off Guadalupe Island, Mexico (Fig. 3). Additional faunas were studied from Middle Miocene and Pleistocene deposits near Ventura, California and from Pliocene deposits near Centerville Beach, California (Fig. 3).

Recent radiometric dates determined on tuff and basalt horizons within the Mohole cores (Kruger, 1964; Dymond, 1966) indicate this sequence ranges from Middle Miocene (ca. $16\pm1\times10^6$ yrs. B.P.) to Pliocene (ca. 4×10^6 yrs. B.P.) in age. Analyses of planktonic faunas corroborate these ages (Martini and Bramlette, 1963; Parker, 1964).

The lowest assemblage examined in the Mohole cores is characterized by rare specimens of "*Globorotalia barisanensis* LeRoy"* and an absence of "*Orbulina*" morphotypes suggesting its equivalence with a portion of the "*Globorotalia fohsi barisanensis*" Zone** of

* *Globorotalia* (*Turborotalia*) *periphroronda* and *G.* (*T.*) *peripheroacuta* of Blow and Banner (1966).

** In the original sense of Bolli (1957; 1966) as opposed to the recent revision of Banner and Blow (1965).

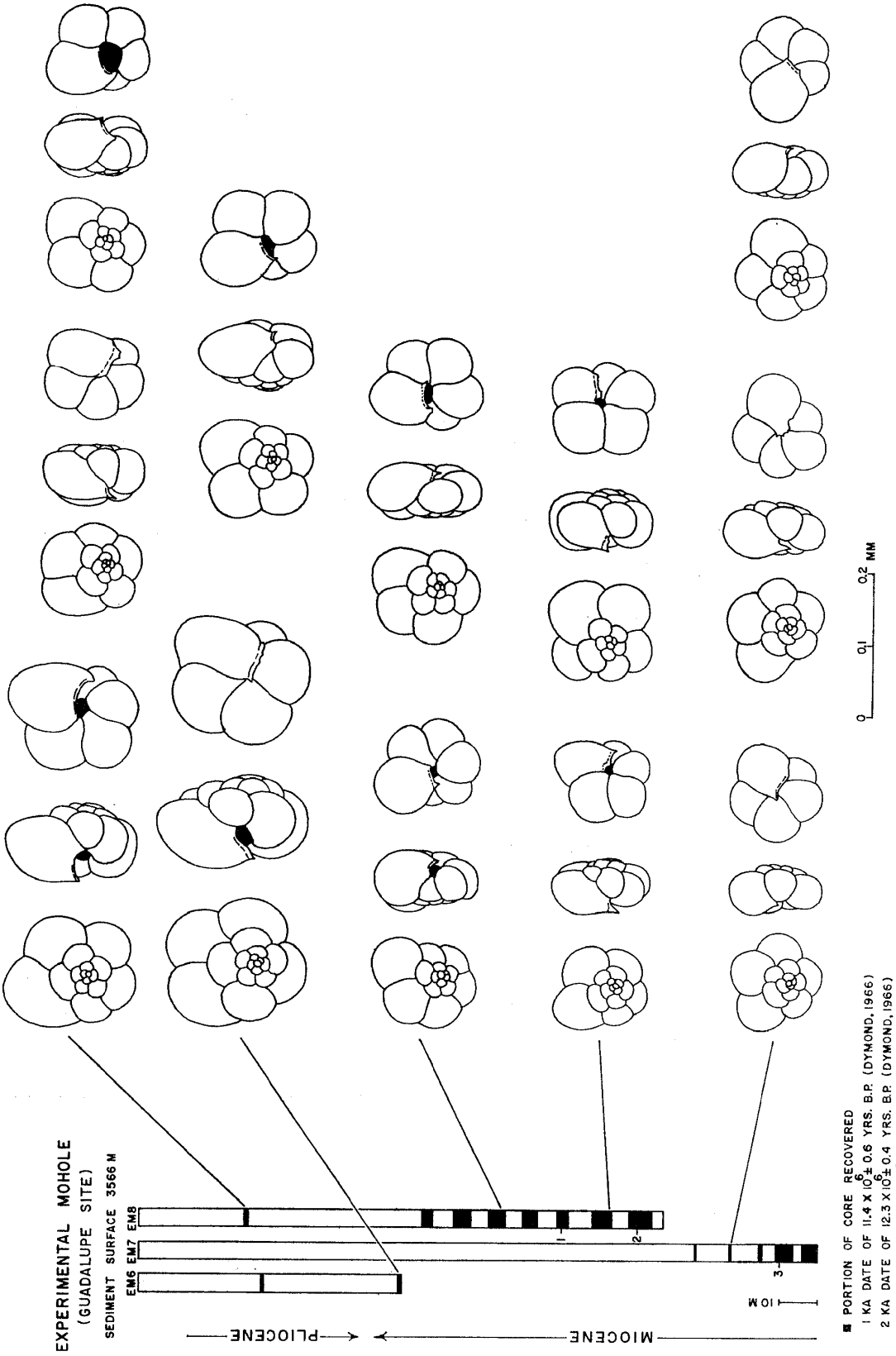


Figure 9. Morphologic variation of specimens comprising the *Globigerina angustiumbilicata-G. quinqueloba* lineage within the Experimenal Mohole cores from near Guadalupe Island, Mexico. Miocene-Pliocene boundary after Parker (1964). Numbered horizons correspond to K-Ar dates obtained by Kruger (1964) and Dymond (1966).

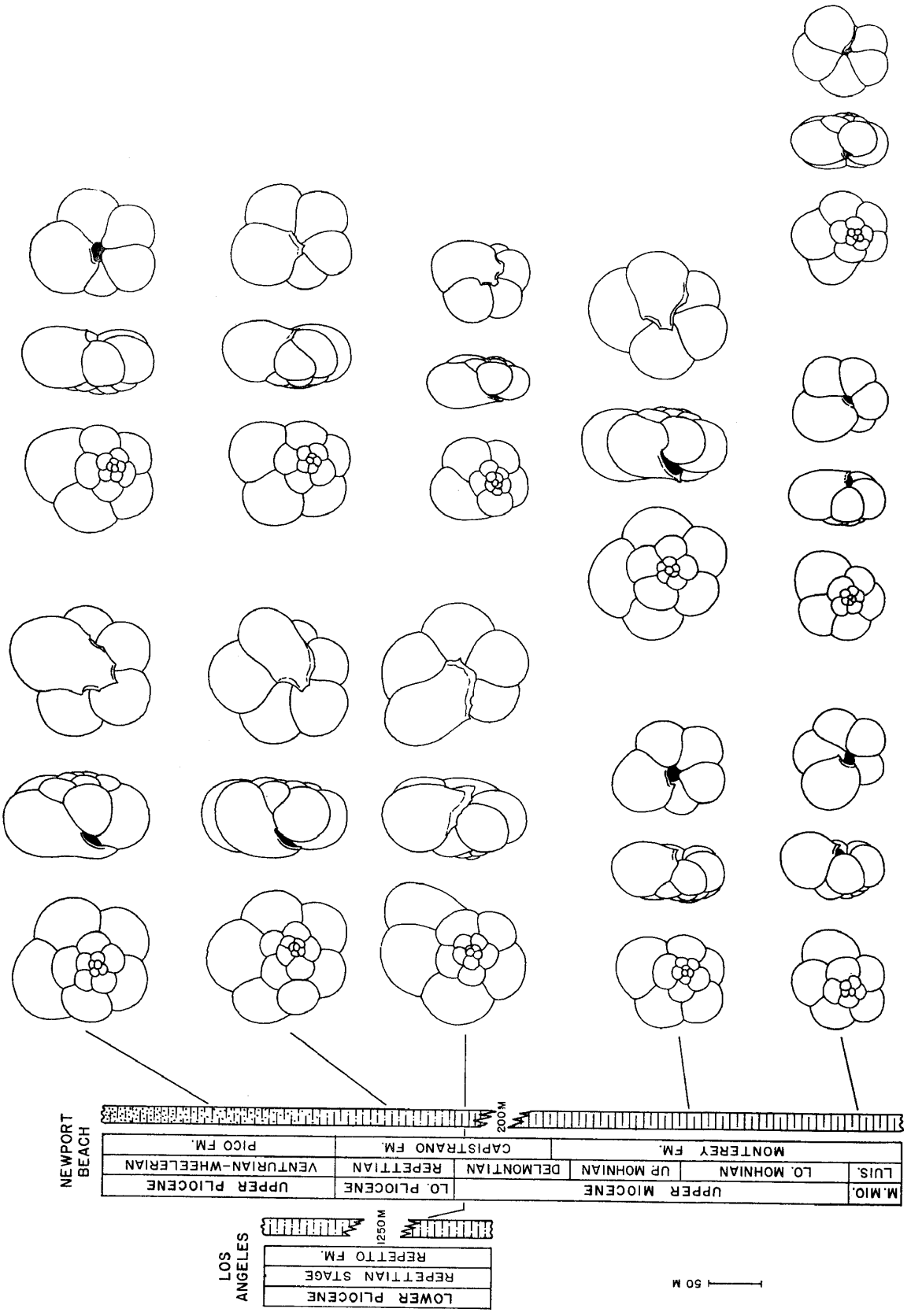


Figure 10. Morphologic variation of specimens comprising the *Globigerina angustiumbilicata-Globigerina quinqueloba* lineage from Middle Miocene through Pliocene deposits of southern California. Stratigraphic columns after Ingle (1967).

tropical latitudes (Fig. 9). The youngest horizon studied within these cores contained *Globorotalia* (*Turborotalia*) *inflata* (d'Orbigny), *G.* (*T.*) *crassaformis* (Galloway and Wissler), and "*Sphaeroidinella dehiscens*" (Parker and Jones) (Fig. 9).

Planktonic faunas within the southern California sequence (Figs. 10 and 11) are similar to those observed in the Mohole cores (Parker, 1964; Ingle, 1966, 1967) except for the expansion of zones due to a greater rate of sedimentation at the continental margin (Fig. 10). The southern California and Mohole sequences are both characterized by a a dominance of temperate and subarctic planktonic populations due to the control of the paleo-California Current system in the eastern North Pacific. Middle Miocene assemblages in this region are dominated by *Globigerina concinna*, *G. angustiumbilicata*, and *G. praebulloides* Blow, whereas *G. bulloides* d'Orbigny, *G. pachyderma* (Ehrenberg) and *G. quinqueloba* dominate Late Miocene through Recent populations (Bandy and Kolpack, 1963; Ingle, 1963; Lipps, 1964; Parker, 1964; Ingle, 1967).

The oldest horizon studied within the southern California epicontinental sequence was from the Middle Miocene Rincon Shale, near Ventura, California (Figs. 3 and 11). The assemblage from this horizon is dominated by *Globigerina concinna*, *G. angustiumbilicata*, *G. praebulloides* and lacks any "*Orbulina*" morphotypes. Although "*Globorotalia barisanensis*" is absent from this fauna, it is equivalent in other aspects to the basal assemblage studied from the Mohole sequence (Fig. 9).

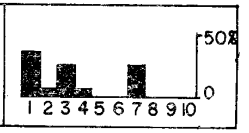
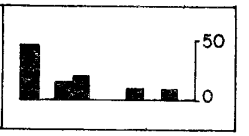
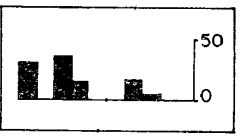
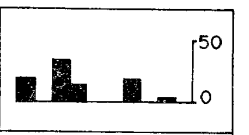
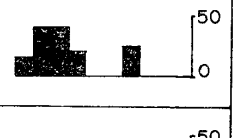
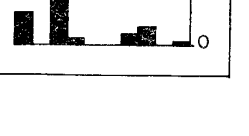
The lowest horizon studied from the Monterey Formation at Newport Beach, California (Fig. 10) is dominated by *Globigerina bulloides s. s.*, *G. bulloides quadrilatera* (Galloway and Wissler), and variants and is approximately equivalent to the basal portion of the "*Globorotalia mayeri*" Zone of the tropics. The youngest horizon within this section (Fig. 10) is considered Upper Pliocene in age as evidenced by the presence of *Globorotalia* (*Globorotalia*) *truncatulinoides* (d'Orbigny) and dextral populations of *Globigerina pachyderma* (Bandy and Ingle, 1967; Ingle, 1967). Measurements made of specimens within a slightly younger Pliocene-Pleistocene population from the Pico Formation near Ventura, California are also presented (Figs. 3 and 11).

To summarize, the Mohole sequence studied (Fig. 9) spans the interval from the Middle Miocene "*Globorotalia fohsi barisanensis*" Zone to the Lower Pliocene "*Sphaeroidinella dehiscens*" datum. The southern California epicontinental sequence presented (Fig. 10) represents the interval from the basal "*Globorotalia mayeri*" Zone to a point in the Upper Pliocene identified locally by the appearance of *Globorotalia* (*Globorotalia*) *truncatulinoides*. Analyses of an older Middle Miocene ("*Globorotalia fohsi barisanensis*" Zone equivalent) population and a younger Pliocene-Pleistocene population from southern California are also presented (Fig. 11).

Illustrations (Figs. 9 and 10) and measurements (Fig. 11) of the *Globigerina angustiumbilicata* — *G. quinqueloba* populations from California and the Mohole cores provide evidence of several morphologic trends with time. The two most apparent trends are an increase in average test diameter and an increase in the percentage of specimens possessing an aberrant final chamber and lip covering the umbilical area (Fig. 11). Measurements illustrate that Middle Miocene populations within the "*Globorotalia fohsi barisanensis*" Zone have an average diameter of 132 microns whereas the Pleistocene population analysed has an average diameter of 235 microns (Fig. 11). There is an associated and more arithmetic increase in the maximum test diameter recorded from progressively younger populations (Fig. 11).

Less than 20 percent of specimens measured within Miocene* populations of this

* The Miocene-Pliocene boundary is placed at the highest occurrence of "*Sphaeroidinellopsis seminulina*" (Schwager) and/or the lowest occurrence of "*Sphaeroidinella dehiscens*" in this report.

		DIAMETER [1] PROLOCULUS	MAXIMUM DIAMETER FINAL WHORL	MAXIMUM DIAMETER PENULTIMATE WHORL	TOTAL NUMBER CHAMBERS	NUMBER CHAMBERS LAST WHORL	COILING [2] RATIO	NUMBER SPECIMENS MEASURED	PERCENT FINAL CHAMBER TYPES
PLEISTOCENE PICO FM. VENTURA, CALIFORNIA	MX.	25	300	188	17	5.0	11/11	22	
	AV.	15	235	116	15	4.9			
	MN.	12	169	81	13	4.5			
LOWER PLIOCENE RIO DELL FM. CENTERVILLE BEACH, CALIF.	MX.	26	238	125	16	5.0	8/12	20	
	AV.	21	189	100	14	4.8			
	MN.	13	150	77	12	4.1			
UPPER MIOCENE MONTEREY FM. (MOHNIAN) NEWPORT BEACH, CALIF.	MX.	26	238	138	16	5.0	8/12	20	
	AV.	16	170	90	13	4.8			
	MN.	10	125	56	11	4.0			
MIDDLE MIOCENE MONTEREY FM. (LUISIAN) NEWPORT BEACH, CALIF.	MX.	25	194	125	18	5.0	13/7	20	
	AV.	15	160	69	15	4.9			
	MN.	10	106	62	13	4.7			
MIDDLE MIOCENE RINCON SHALE (U. RELIZIAN) N. VENTURA, CALIF.	MX.	23	175	90	16	5.5	13/7	20	
	AV.	15	132	71	13	5.0			
	MN.	10	100	50	10	4.0			
MIDDLE MIOCENE MOHOLE CORE EM-7 (7-10 CM) NEAR GUADALUPE ID., MEXICO	MX.	21	163	87	15	5.0	9/11	20	
	AV.	16	132	68	13	4.7			
	MN.	12	112	50	11	4.2			

[1] MEASUREMENTS IN MICRONS
[2] SINISTRAL / DEXTRAL

MX. = MAXIMUM
AV. = AVERAGE
MN. = MINIMUM

Figure 11. Measurements and coiling characterisitics of specimens comprising the *Globigerina angustiumbilicata-G. quinqueloba* lineage from various Middle Miocene through Pleistocene deposits in California and the Experimental Mohole cores. See Table 1 and Figure 4 for key and illustration of final chamber types noted above.

lineage possessed an aberrant final chamber and lip covering the umbilical area (including forms with a bulla and infralaminal apertures). More than 40 percent of the Pliocene and Pleistocene populations studied possessed these features (Fig. 11).

Additional and more subtle trends noted include the appearance of distinctly hispid-spinose tests within Upper Miocene populations. This trait is first associated with the earliest occurrences of *Globorotalia* (*Globorotalia*) *menardii menardii* (Parker, Jones and Brady) in the Mohole cores and in Mohnian Stage sediments of the Monterey Formation at Newport Beach, California (Figs. 9 and 10). A subtle trend was also noted toward an increase in the total number of chambers (Fig. 11). Coiling within the populations studied was found to be essentially random (Fig. 11).

Marginal Western North Pacific

Tropical and subtropical planktonic foraminiferal biofacies characterize the Neogene deposits of Kyushu, Shikoku, and Honshu islands in contrast to the temperate-subarctic planktonic biofacies present in the marginal eastern North Pacific. Nevertheless, Neogene assemblages from northern Honshu contain significant percentages of temperate-subarctic species and in some instances these forms predominate (Saito, 1963; Takayanagi and Oba, 1966). Populations of the *Globigerina angustiumbilicata—G. quinqueloba* lineage were studied from Middle Miocene through Pliocene deposits in northern and western Honshu (Fig. 3).

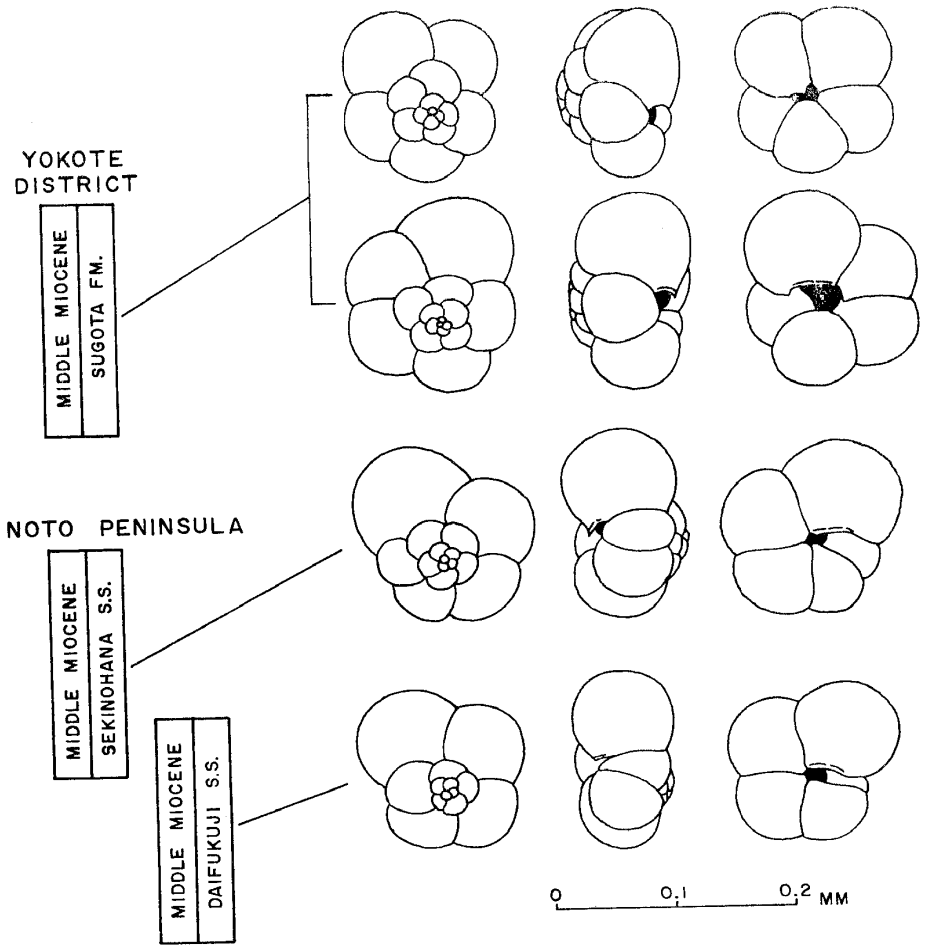


Figure 12. Morphologic variation of forms within the *Globigerina angustiumbilicata-G. quinqueloba* lineage from Middle Miocene deposits of northern and western Honshu, Japan.

The oldest population studied in this area was obtained from the Middle Miocene Daifukuji Sandstone of the Noto Peninsula (Fig. 12). This fauna contains common specimens of *Globorotalia* (*Turborotalia*) *peripheroronda* Blow and Banner with *Globorotalia* (*Turborotalia*) *scitula praescitula* (Blow) and *Globigerina praebulloides* comprising the most abundant faunal members. Populations from a horizon of similar age were obtained from the Middle Miocene Sugota Formation of the Yokote Basin (Fig. 12). This fauna is also characterized by *Globorotalia* (*Turborotalia*) *peripheroronda* along with an abundance of *G.* (*T.*) *scitula praesictula*, *Globigerina angustiumbilicata*, and *G. praebulloides*. Populations from a somewhat younger horizon were studied from the Miocene Sekinohana Calcareous Sandstone of the Noto Peninsula (Fig. 12). This fauna is characterized by common specimens of *Globorotalia* (*Globorotalia*) *praemenardii* Cushman and Stainforth in association with *Globigerinoides trilobus* (Reuss) and within tropical element. This assemblage is interpreted as representing an interval immediately above or within the highest portion of the

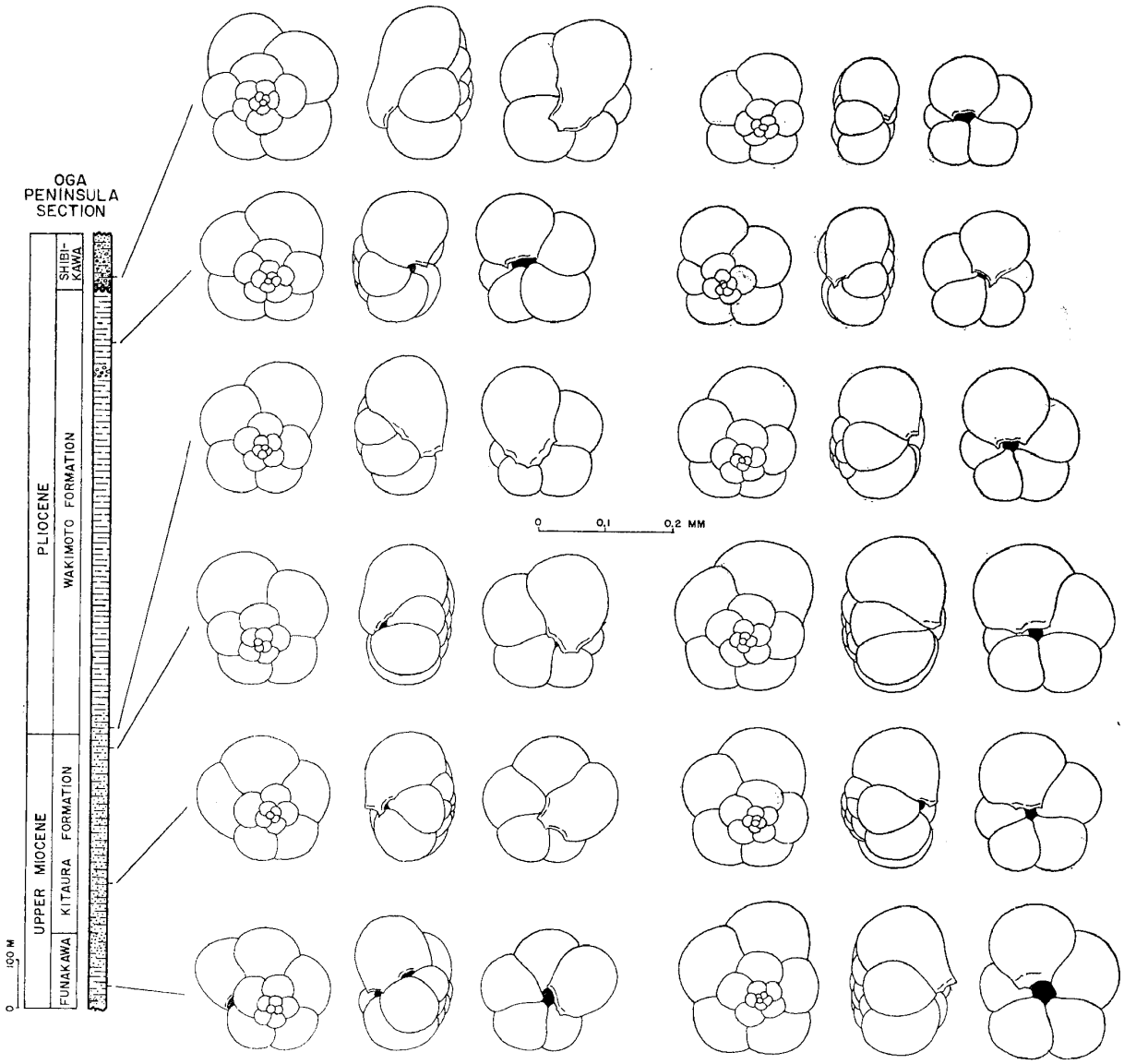


Figure 13. Morphologic variation exhibited by specimens of *Globigerina quinqueloba* from Upper Miocene and Pliocene deposits of Oga Peninsula, Japan. Stratigraphic column after Takayanagi and Oba (1966).

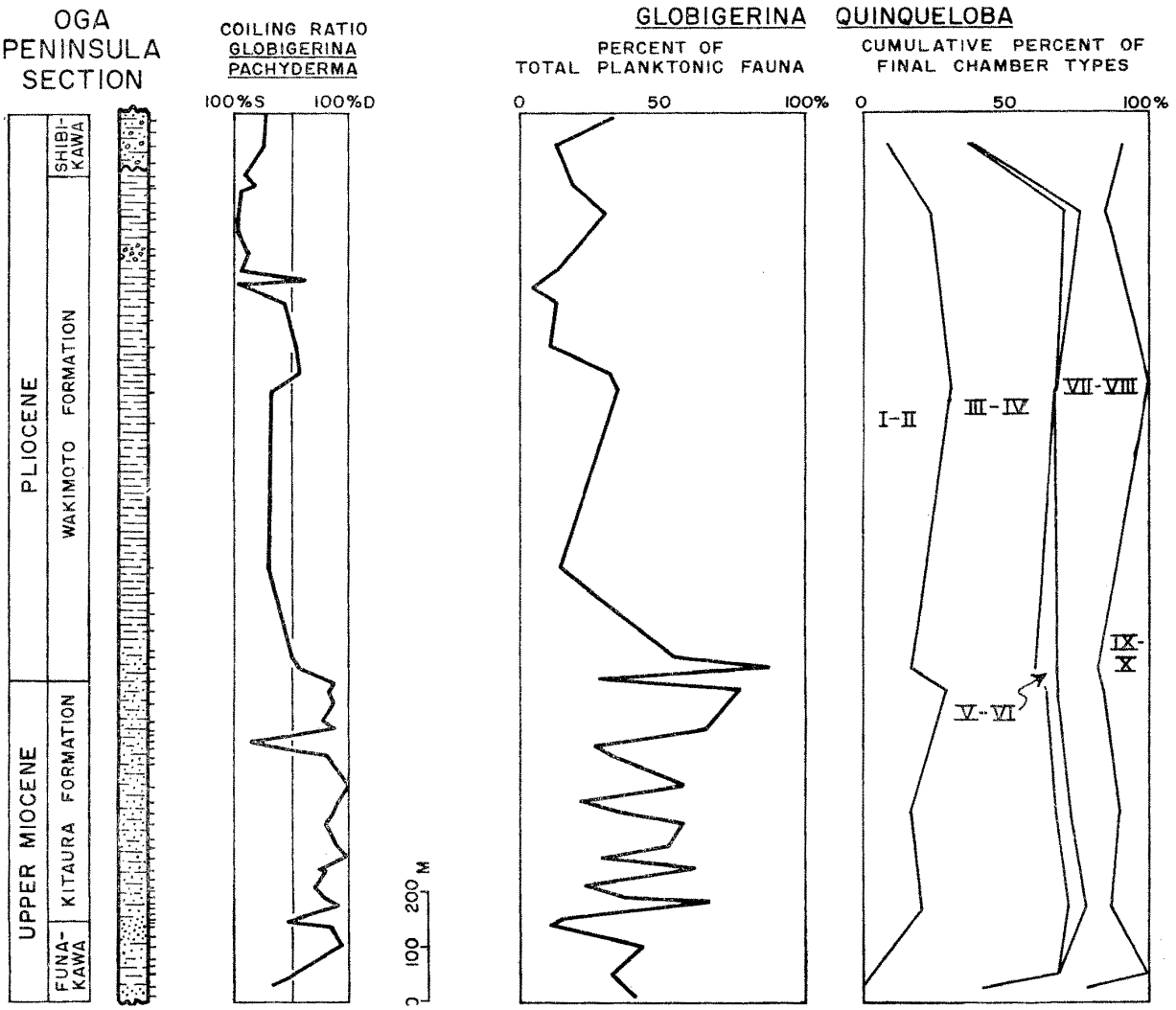


Figure 14. Cumulative percentage of various final chamber types and relative abundance of *Globigerina quinqueloba* within Miocene and Pliocene deposits of Oga Peninsula, Japan. Stratigraphic column and coiling ratio of *Globigerina pachyderma* after Takayanagi and Oba (1966). Sinistral populations of *G. pachyderma* infer surface temperatures less than 11°C in light of Recent distributions (Ericson, 1959; Bandy, 1960). See Table 1 and Figure 4 for key and illustrations of various final chamber types noted above.

"*Globorotalia fohsi fohsi*" Zone of tropical latitudes.

Upper Miocene and Pliocene populations were obtained from a section through the Funakawa, Kitaura, Wakimoto, and Shibikawa formations of the Oga Peninsula (Fig. 13). Takayanagi and Oba (1966) have recently analysed planktonic faunas within this section. These workers noted the highest occurrence of "*Sphaeroidinellopsis seminulina*" within the Kitaura Formation and placed the Miocene-Pliocene boundary at the top of this unit (Fig. 13). The planktonic faunas from this section are dominated by *Globigerina bulloides*, *G. pachyderma*, and *G. quinqueloba* similar to Upper Miocene through Recent assemblages in California (Ingle, 1967). A change from dextral to sinistral coiling preference of *G. pachyderma* within this section indicates that water temperature dropped below 11°C in this area during a portion of the Pliocene (Fig. 14).

Middle Miocene ("*Globorotalia fohsi barisanensis*" Zone) populations of the *Globigerina angustiumbilicata* — *G. quinqueloba* complex in Honshu (Fig. 12) exhibit similar character-

istics to populations found within the equivalent interval in the eastern Pacific (Figs. 9, 10, and 11). Average test diameter is 170 microns or less; test walls are commonly smooth to very finely hispid and translucent. Tests possessing final chamber forms III, VII, and VIII (Table 1, Fig. 4) predominate whereas tests possessing a bulla or aberrant final chamber forms I or II are rare or absent (Fig. 12). Interestingly, the population studied from the Sugota Formation of the Yokote Basin in northern Honshu (Fig. 12) most closely resembles the Middle Miocene populations from California and the Mohole cores. This resemblance reflects the similarity in composition of temperate planktonic biofacies on both sides of the North Pacific during the Middle Miocene.

Specimens of the *Globigerina angustiumbilicata—G. quinqueloba* lineage were not analysed from horizons equivalent to the "*Globorotalia mayeri*" Zone in Honshu. However, this lineage is continuously present within deposits of this interval as reported by Saito (1963).

Populations present within the Upper Miocene Funakawa and Kitaura formations of Oga Peninsula (Fig. 15) are essentially identical with Recent populations (Figs. 13, 14, 15) as are specimens from the overlying Pliocene units. Average test diameter exceeds 200 microns and most specimens exhibit an opaque and prominantly spinose test. Moreover, up to 30 percent of the specimens within a given horizon possess the aberrant final chamber and extended lip considered characteristic of *Globigerina quinqueloba* (Fig. 14).

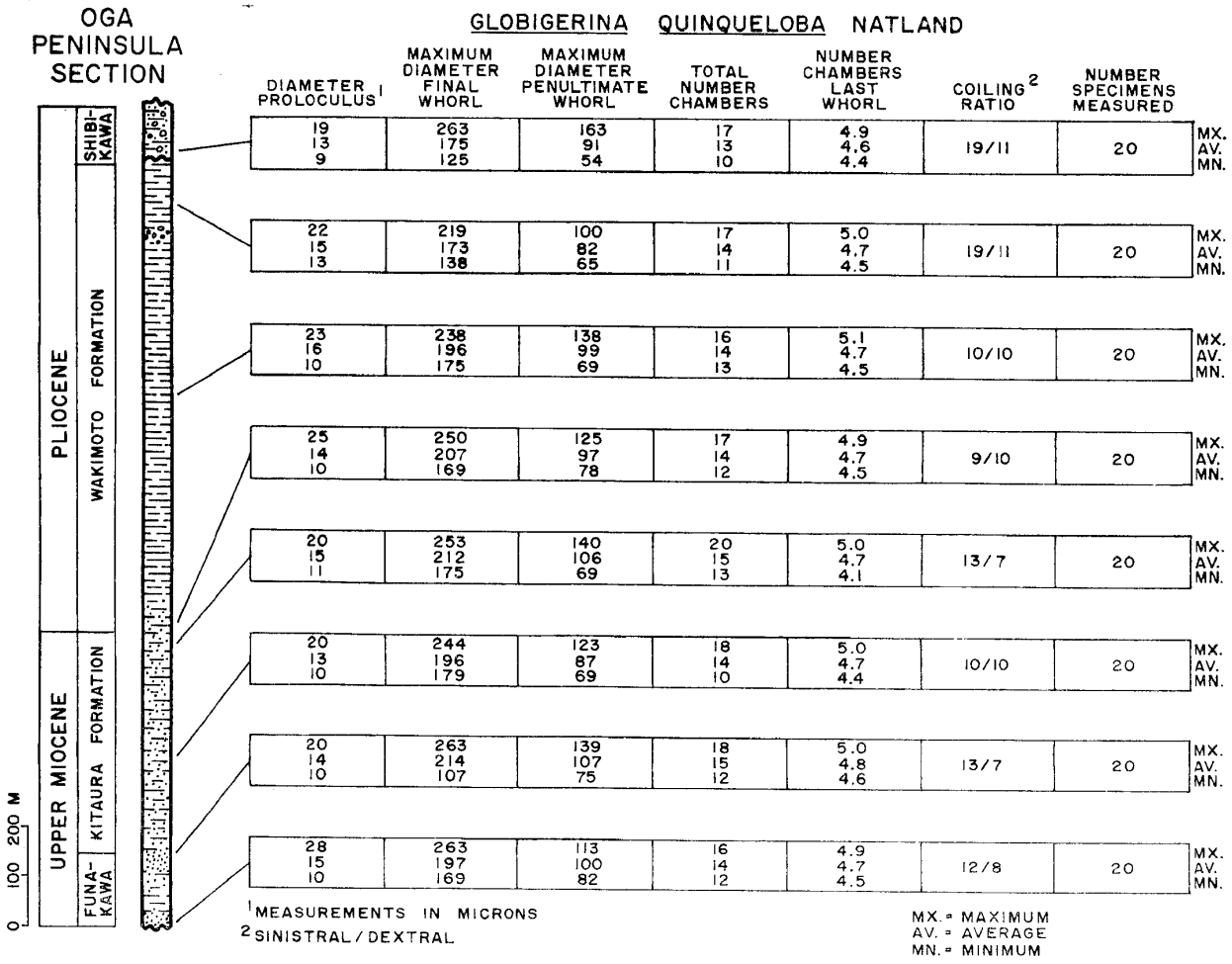


Figure 15. Measurements and coiling cnaracteristics of *Globigerina quinqueloba* from the Upper Miocene and Pliocene of Oga Peninsula, Japan. Stratigraphic column after Takayanagi and Oba (1966).

A correlation was sought between final chamber form and paleoecologic parameters by plotting percentages of various final chamber types, percentage of *Globigerina quinqueloba* in the total planktonic fauna, and the coiling ratio of *G. pachyderma* within the Oga Peninsula section (Fig. 14). Inspection of Figs. 14 and 15 illustrates that percentage of the various final chamber types and other morphologic characteristics remained constant through the interval studied, despite variation in water temperature inferred by changes in the coiling direction of *G. pachyderma*. Correlation between water temperature and test morphology must await future studies on living populations. The present analysis (Figs. 14 and 15) suggests the morphology of the lip and final chamber are governed by other parameters. However, abundance of *G. quinqueloba* appears to be directly related to apparent changes in water temperature within the Miocene-Pliocene section (Figs. 14 and 15) as is the case with living populations (Bradshaw, 1959; Bé, 1960; Parker, 1962). Percentage of *G. quinqueloba* decreased markedly in the Pliocene coincident with intervals dominated by sinistral populations of *G. pachyderma*.

In summary, Middle Miocene populations of the *Globigerina angustiumbilicata—G. quinqueloba* complex studied from Honshu exhibit a similar range in size and morphologic variation as populations from the same interval in the eastern North Pacific. Latest Miocene and Pliocene populations are essentially identical in character with Recent populations again duplicating trends found within contemporaneous deposits in California.

SUMMARY AND DISCUSSION

The most straightward manner of assessing morphologic differences within the *Globigerina angustiumbilicata—G. quinqueloba* lineage with time is to compare the oldest populations examined with Recent populations. Reviewing measurements and illustrations of specimens from horizons within Middle Miocene and Recent populations (Figs. 6, 7, 9–15), the two most outstanding differences appear to be in test diameter and predominant final chamber form. The average diameter of the Middle Miocene forms is 132 to 170 microns, whereas the average diameter of Recent forms is consistently greater than 200 microns with some well developed specimens attaining 300 microns. Counts and illustrations indicate that there is also an increase in the percentage of specimens exhibiting final chamber type I (Table 1, Figs. 4 and 16) with time.

In addition to the above differences, qualitative observations revealed Recent specimens commonly possess a coarsely hispid test surface, whereas most Middle Miocene individuals exhibit a smooth or very finely hispid test surface. The hipsid nature of the test surface is a reflection of the spinosity of the living animals. Parker (1962) has already emphasized the hispid-spinose nature of Recent specimens of *Globigerina quinqueloba*, and Bolli (1957) noted the smooth test surface of Oligocene and Miocene specimens of *G. angustiumbilicata*. It must be noted, however, that the surface of Recent specimens of *G. quinqueloba* acquiring of a secondary thickening of the test wall lose their hispid character. Recent studies illustrate such secondary deposits of $CaCO_3$ take place as a foraminifer descends through the water column during its life cycle (Bé, 1965; Bé, McIntyre and Breger, 1966). A parallel example may be manifest in the Oligocene* morphotype *Globigerina angulisuturalis* leading to the characteristic U-shaped sutures ascociated with this form. Upper Miocene through Recent specimens of *G. quinqueloba* can be found which exhibit identical U-shaped sutures due to the addition of a thick $CaCO_3$ crust (Fig. 4).

In the light of the differences between Middle Miocene and Recent populations it is instructive to note the stratigraphic distribution of selected morphologic characters within

* In the sense of Bolli (1966).

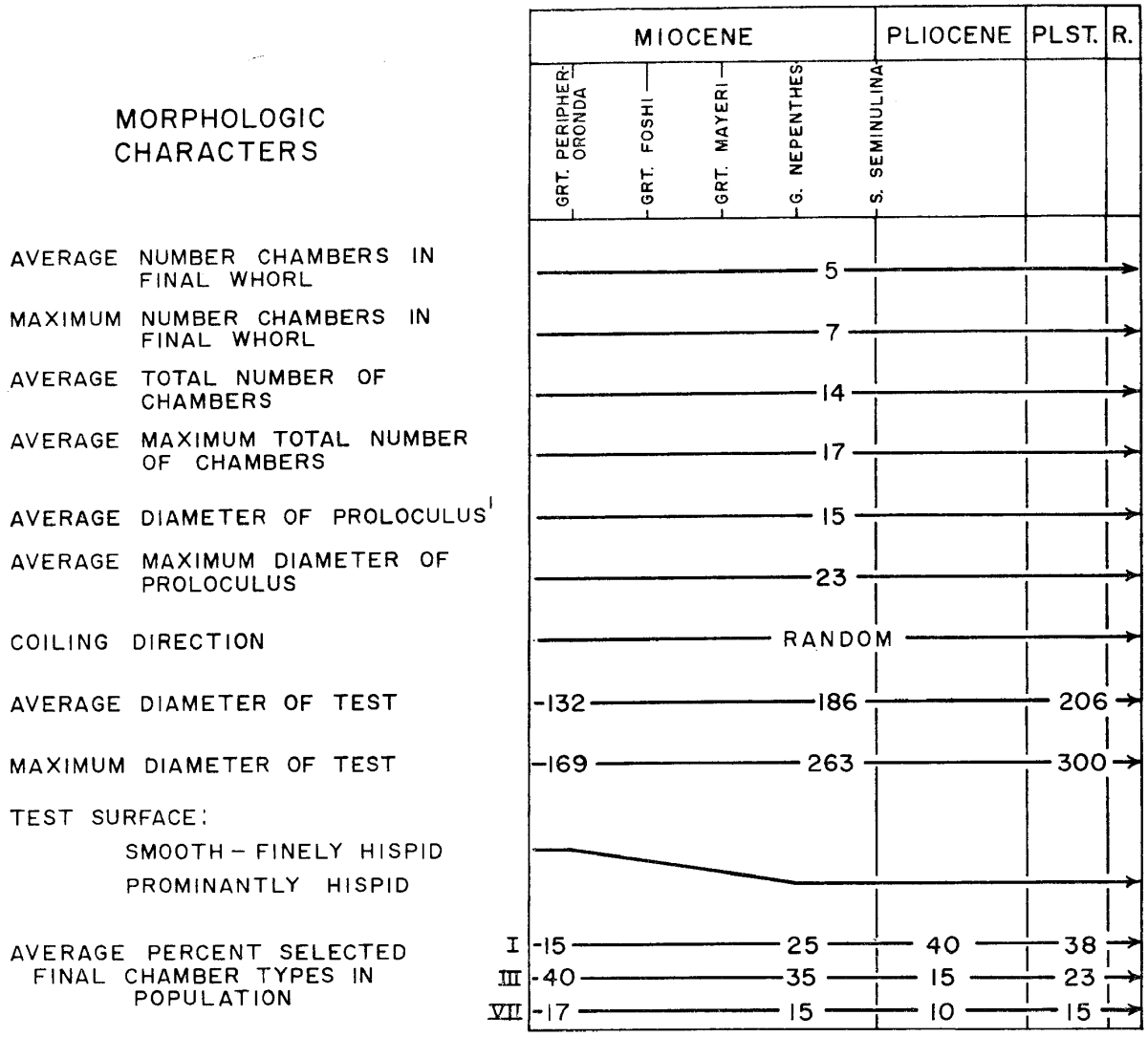


Figure 16. Summary diagram of selected morphologic characters studied within the *Globigerina angustiumbilicata-G. quinqueloba* lineage in Middle Miocene through Recent populations of the marginal North Pacific. See Table 1 and Figure 4 for classification of final chamber types referred to in the above diagram. Range of morphologic characters are placed against a scale defined by the upper stratigraphic limits of characteristic planktonic species common to warm temperate and tropical regions.

the interval studied. A summary diagram of selected characters within the various populations of the lineage (Fig. 16) clearly indicates some of the problems involved in attempting a practical definition of species.

Variation of Morphology with Time

The limits and average expression of the number of chambers in the final whorl, total number of chambers, diameter of the proloculus, and coiling preference remain essentially constant throughout the Middle Miocene to Recent interval (Fig. 16). Nevertheless, diameter of the test, percent of selected final chamber types, and predominance of coarsely hispid tests show variation with time leading to the differences noted above. Increase in test diameter and variations of final chamber forms exhibit long period

trends whereas the change from predominantly smooth to predominantly coarsely hispid test surface occurs during a relatively short interval.

Final Chamber Types

Bolli, Loeblich, and Tappan (1957, p. 15) have noted that one of the principal evolutionary trends within planktonic Foraminifera is the tendency to develop structures covering the aperture. This trend is clearly expressed within the *Globigerina angustiumbilicata—G. quinqueloba* lineage. The oldest population examined by the writers from the "*Globigerina ciperoensis ciperoensis*" Zone possessed only final chamber shapes of simple form along with a simple aperture and thin lip (final chamber types VII-X of this report). Middle Miocene populations include forms with a prolonged final chamber and lip covering a portion or all of the aperture and umbilical area (Figs. 9, 10, and 11). The most extreme manifestation of this trend is the formation of a bulla with infralaminal apertures. Specimens possessing this character are included within final chamber type I (Fig. 4, Table 1). This character was emphasized in the type description of *Globigerina quinqueloba* (Fig. 5), although specimens with simple final chambers and apertures are present in Recent populations (Figs. 6 and 7).

The percentage of specimens possessing final chamber type I in North Pacific deposits increases from 15 percent in some Middle Miocene populations to a maximum of 50 percent of some Recent populations (Figs. 7 and 11). Data thus suggest that there has been a pronounced trend from simple aperture and final chamber form in the Oligocene to an increasingly aberrant final chamber and lip covering the umbilical area. Interpretation of this trend is complicated by the fact that some Recent populations of *Globigerina quinqueloba*, notably those in the North Atlantic (Bé and Hamlin, 1967), lack individuals possessing final chamber type I. Specimens with this final chamber form are also rare or lacking in other high latitude Recent deposits (Fig. 7; Lipps and Warme, 1966), suggesting this character is perhaps related to water temperature.

Variation in Size

Differences in size among individuals are generally scorned as a means of establishing taxonomic units. A progressive increase in maximum diameter of the final whorl is apparent in the interval studied (Fig. 16) leading to a significant difference in the median diameter of Middle Miocene and Recent populations. Although variation in size of individuals most certainly reflects environmental differences or ontogenetic development in some cases the persistent trend of increasing diameter with time is thought to represent an evolutionary trait. This interpretation is strengthened by the fact that the same trend is apparent in progressively younger populations from opposite sides of the North Pacific.

Separation of Species

The summary diagram (Fig. 16) thus demonstrates the consistency of some characteristics within the Middle Miocene to Recent interval and the progressive and subtle variation of others. The overall picture is one of a slowly evolving temperate-water planktonic population exhibiting subtle morphologic gradations from one horizon to the next. The slow differentiation within this lineage can be contrasted with the apparently rapid and drastic morphologic variation with time among numerous tropical Neogene planktonic species as exemplified by the *Globorotalia fohsi s. l.* lineage. Slow and subtle morphologic differentiation over a lengthy geologic interval is an apparent trait of many boreal planktonic species and is responsible for their apparent long stratigraphic ranges. It is possible to demonstrate a significant difference between some of the median characteristics of Middle Miocene populations and those of Recent populations studied. However, it

is extremely difficult to place a meaningful stratigraphic boundary between the two species analysed. The basic question remains as to what criteria can be used to clearly separate *Globigerina angustiumbilicata* from *G. quinqueloba*, or more practically speaking, what are the upper and lower stratigraphic limits of the two species?

It is apparent that if one resolves this question by reference to the type descriptions and specimens of the two species (Fig. 5) that the decision is relatively easy; a mature specimen not conforming to the limits of the type of either species is rejected. Unfortunately, nature produces populations and it is abundantly clear in the case described that the wide range in morphology exhibitied within populations from a given horizon nullifies the strict use of the narrow limits imposed by the type descriptions.

Throughout this report the writers have attempted to describe characteristics of populations rather than individuals. The concept of population limits rather than individual limits is foreign to most discussions and descriptions of planktonic Foraminifera with the exception of Parker (1962) and Wade (1964). Most authors refer to a given species in terms of the type description despite the fact that in reality significant numbers of individuals within a given species population deviate considerably from the type. A basic question thus confronting students of micropaleontology is whether one should speak of populations of a species or simply individuals. In either case what are the limits to be defined in differentiating such simple morphotypes as those analysed in this report? The writers cannot offer any new solutions to the basic question of what constitutes a species*. Nevertheless it is interesting and profitable to review several possible methods of differentiating species within the lineage studied along with the problems inherent in each. In the end each investigator must choose the limits to be placed on a given morphotype. This problem is exaggerated in the case of abundant, ubiquitous, planktonic species of simple character.

Spinosity

One can argue that of the three morphologic characters showing variation with time within the lineage studied (Fig. 16), size and final chamber shape are not reliable for taxonomic differentiation. Both of these characters may simply reflect ecophenotypic variation within a given population as shown by differences among Recent populations from various areas (Fig. 7).

Eliminating these two parameters and considering the consistency of other morphologic characters measured (Fig. 16) leaves only variation in spinosity of the test to be utilized in differentiating the two species. A trend from smooth to hispid-spinose test wall seems to be present within the lineage which in turn likely reflects a subtle change in microstructure of the wall. Thus one could arbitrarily separate the two species on the basis of presence or absence of a hsipid-spinose wall. However, the validity of this trend must be tested by thin sectioning; Lipps (1966) has already pointed out the inconsistency of test surfaces as an expression of wall microstructure. Moreover, assuming the validity of even a subtle change in wall microstructure with time, such as an increase in the number of spines per unit area, presents a basic question as to taxonomic significance of wall structure. Differences in microstructure of the test wall are currently being used to differentiate family groups (Parker, 1962; Lipps, 1966) thus it hardly seems reasonable that it can be used to differentiate species. Also, the separation of various morphotypes into species on the basis of variation in only one character is inconsistent with generally accepted taxonomic practice.

* See Mayr (1957).

Gradational Forms

Upon rejecting the use of a single variable to separate the two species one must seek another method. It is common practice in the literature to recognize gradations between closely related species (Bolli, 1957; Blow, 1959; Wade, 1964); these forms are referred to as gradational, transitional, or intermediate morphotypes. If the "gradational forms" can be identified, possess identifiable morphologic characteristics, and limits are placed on their stratigraphic ranges, do they not constitute a new species in terms of the current concepts in use? The use of the term "gradational form" simply multiplies the arbitrary boundary between species. Upper and lower stratigraphic limits of a "gradational form" division are commonly assigned at a given level. One can easily apply the "gradational form" concept to solve the dilemma within the *Globigerina angustiumbilicata—G. quinqueloba* lineage. Noting the specific and identifiable differences between Middle Miocene ("*Globorotalia fohsi barisanensis*" Zone) forms and Late Miocene through Recent forms, the former can be assigned to *G. angustiumbilicata* and the latter to *G. quinqueloba*. The interval encompassing the "*Globorotalia mayeri*" and "*Globorotalia menardii*" Zones can thus be assigned to "gradational forms". Of course "gradational forms" also occur in the horizontal sense causing a complication in the use of this term. Finally, if one employs the term "gradational form" stratigraphically then only the stratigraphic mid-points of either species will be meaningful or useful because the upper and lower boundaries will consist of intermediate or "gradational forms".

Use of Statistical Limits

A third method for dividing the morphoseries from *Globigerina angustiumbilicata* to *G. quinqueloba* is to assign strict statistical limits for each species. Again, there is the question as to whether limits should be set for the recognition of a population or the recognition of individuals. For example, arbitrary individual or population limits can be chosen for the recognition of *Globigerina quinqueloba* simply using the three variable characters of the lineage; size, spinosity, and final chamber shape. On an individual basis any mature specimen within a given population of the lineage exhibiting a diameter greater than 200 microns, a coarsely hispid test, and possessing final chamber type I or II (Table 1) could arbitrarily designate *G. quinqueloba*. In view of the gradational series demonstrated such an individual would initially be found at some horizon within the "*Globorotalia mayeri*" Zone (Fig. 16) and provide an absolute lower stratigraphic limit of the species.

A more realistic definition of the species, in the biological sense, would be to select population limits. Noting the constant character of a number of morphologic parameters in all populations studied (Fig. 16) emphasis can again be placed on size, spinosity and final chamber shape. Populations in which the median test diameter exceeds 200 microns, more than 80 percent of mature* specimens exhibit a distinctly hispid test, and 30 percent or more of the mature specimens possess final chamber type I can arbitrarily be termed *Globigerina quinqueloba*. Populations with these characteristics first appear within deposits equivalent to the "*Globorotalia menardii*" Zone. Unfortunately, time necessary to determining population characteristics limits the practicability of this method in biostratigraphy. Nevertheless, most students of planktonic Foraminifera work on this level in a qualitative way as evidenced by the persistent recognition of "gradational forms" between given morphotypes. Moreover, quantitative data on populations from various sequences in New Zealand has recently been employed to define and name a "gradational form" between *Globorotalia miozea* and *G. crassaformis* (Kennett, 1966a). Blow and Banner

* Analyses indicate mature specimens within this lineage possess an average of 14 chambers (Fig. 16) within the interval studied.

(1966) have also recently employed semi-quantitaive methods to the separation of species within the *Globorotalia fohsi s.l.* lineage. Furthermore, Blow and Banner's recognition of specimens representing the median characteristics of a given population seems inherent in their use of the term "forma typica" although their species definitions are based on individuals (primary types) rather than populations.

Conclusions

The morphologic analysis presented clearly illustrates a long period gradational morphoseries from *Globigerina angustiumbilicata* to *G. quinqueloba*. The subtle nature of variation among simple morphologic characteristics from the Middle Miocene to Recent precludes a clearcut separation of the two species in the Upper Miocene. The traditional method of solving this dilemma is to employ the term "gradational form" for specimens intermediate in character between end members of a lineage. Analysis of populations rather than individuals illustrates that "gradational forms" are present in varying percentages in populations of all horizons studied and horizontally within a given level. Thus the use of this term simply begs the question. Of the morphologic parameters studied, hispidity of the test surface appears to be least affected by ecologic stresses at any given level and likely represents an evolutionary trait. The apparent change from smooth test surfaces in the Oligocene to distinctly hispid-spinose walls in the Upper Miocene may prove to be a valid criteria for separation of the two species. This problem must be solved by a study of thin sections.

The study of populations rather than individuals has emphasized the difficulty of restricting species definitions to the strict limits imposed by reference to the type specimens alone. Unfortunately, the simple morphologic nature of endemic temperate and boreal planktonic species allows wide variation of characteristics at any given stratigraphic horizon. The present analysis indicates only three morphologic characteristics undergo significant change with time and are of use in separating *Globigerina angustiumbilicata* from *G. quinqueloba*; these are size, spinosity, and final chamber form. Independent of whether species limits are set on the basis of individuals or populations it is concluded that *Globigerina quinqueloba* made its first appearance in the North Pacific in the Upper Miocene. On the basis of arbitrarily selected morphologic limits individuals assigned to *G. quinqueloba* first appeared within the "*Globorotalia mayeri*" Zone whereas populations appeared initially within the "*Globorotalia menardii*" Zone.

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ADDENDUM

After this paper was sent to the press some opinions on the Pliocene-Pleistocene boundary have been expressed by Parker (1967), Hays and Berggren (1967 MS), and Berggren *et al.* (1967). The readers are referred to their papers.

Berggren, W. A., Philipps, J. D., Bertels, A. and Wall, D., 1967, Late Pliocene-Pleistocene stratigraphy in deep sea cores from the south-central North Atlantic. *Nature*, v. 216, no. 5112, p. 253–255, 2 text-figs.

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A condensed summary of the paper "*Globigerina quinqueloba* Natland; origin and distribution in the Late Cenozoic of the North Pacific" was presented to the 4th Mediterranean Neogene Congress in Bologna (Sept., 1967). This paper concerns *Globigerina quinqueloba* in the Late Cenozoic; and the readers are referred to it.